

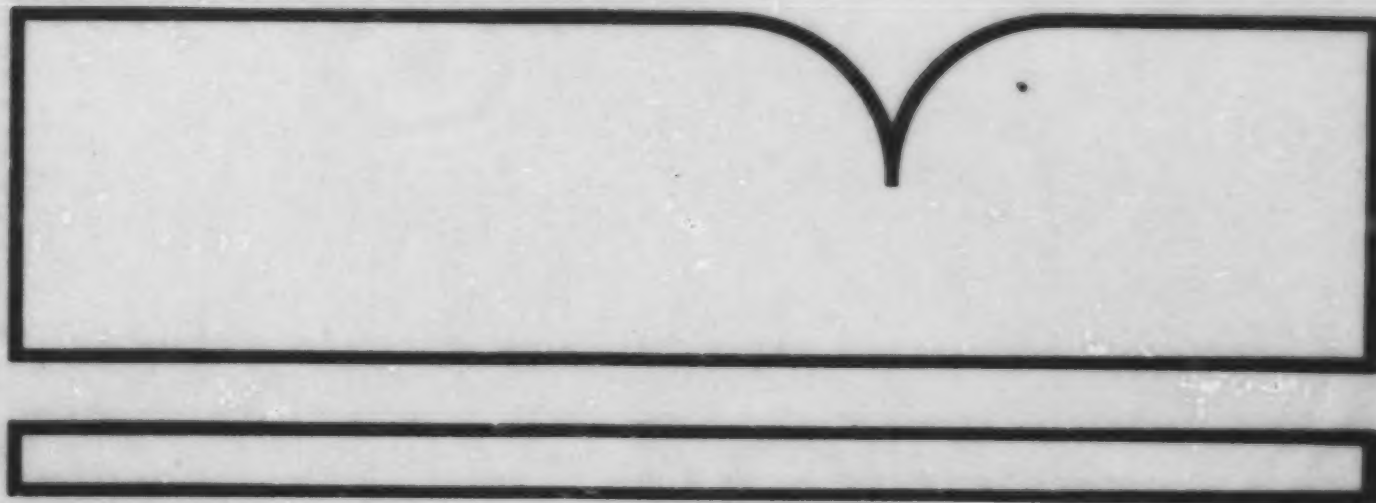
In-Place Burning of Prudhoe
Bay Oil in Broken Ice

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**IN-PLACE BURNING OF PRUDHOE BAY OIL
IN BROKEN ICE**

by

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ABSTRACT

Small-scale and large-scale experiments were performed at the U.S. Environmental Protection Agency's OHMSETT facility to explore the range of conditions in which oil slicks of Prudhoe Bay crude can be burned in broken ice and to determine the efficiencies of such burns.

In laboratory experiments, the minimum slick thickness to support combustion was found to be 2.5 mm on brackish water at temperatures from 2C to 6.5C. Minimum slick thickness to support combustion on brackish water at temperatures from 18C to 22C was found to be 2 mm. The wicking agent was found to vary in effectiveness as a burn-enhancing agent. Decreases in burn efficiency and burn rates were observed with decreasing water temperatures.

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This program was sponsored by the OHMSETT Interagency Technical Committee (OITC), which includes the Minerals Management Service, U.S. Coast Guard, Canadian Environmental Protection Service, U.S. Environmental Protection Agency and the U.S. Navy.

INTRODUCTION

In-place burning of Prudhoe Bay crude oil slicks was demonstrated and evaluated at the United States Environmental Protection Agency's Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) in Leonardo, New Jersey during February, 1984. These tests were catalysed by demonstrations performed in an onshore pit near Prudhoe Bay, Alaska in 1983 (Shell Oil Co., et al.). Fifty-five (55) % to 85% of the Prudhoe Bay crude oil distributed among scattered ice was burned off in two burn demonstrations. To provide additional data on burn efficiencies and to explore the range of conditions in which in-place burning of oil slicks can be achieved, a series of laboratory and tank tests were performed at OHMSETT. Ice cover, wave conditions, slick thickness, and degree of oil-weathering were varied in the tests. Preliminary laboratory experiments were performed to anticipate larger-scale burn behavior and to establish minimum conditions to support combustion. Burning effectiveness was quantified by percentage burned.

Minimum slick thickness to support combustion was determined from the laboratory tests as well as certain trends in burn behavior. Burning efficiencies were determined for each of the tank tests and this data was compared to the range of values reported from previous burn tests. (Buist, et al., 1983; Dickens and Buist, 1981; Pistuzak, 1981; Ross, 1983, Shell Oil Co., 1983; and Twardus, 1980.)

LABORATORY TESTING

Summary plan

Burn behavior was investigated and the test oil was characterized in the OHMSETT laboratory prior to the tank tests. The burn behavior tests determined minimum slick thickness needed to support combustion, burn rates, and the increase in burn efficiency due to the addition of a fumed silica wicking agent. A small aluminum ring (approximately 60 mm in diameter) enclosed the oil slick which ranged from 2 to 10.5 mm thick for these tests. The tests were performed on cold ($<6.5^{\circ}\text{C}$) and room temperature (20°C to 24°C) saline tank water. The Prudhoe Bay crude oil was characterized by a series of ASTM tests.

Minimum slick thickness to support combustion

The minimum slick thickness to support combustion was determined in a rectangular aluminum pan approximately 26 centimeter (cm) x 47 cm x 10 cm deep filled with approximately 4 liters of brackish tank water (salt content 20 parts per thousand) and ice (fresh water) if called for. The small aluminum ring (previously mentioned) was supported on 3 aluminum legs in the center of the rectangular pan and oil was distributed from a syringe into the small ring until a continuous slick was formed. The slick thickness was measured using a 2-mm (approximate) diameter steel wire curved into a U-shape. The wire was inserted into the water and raised slowly so that one leg of the "U" penetrated the center of the slick. The length of the residual

oil film adhering to the wire was then measured. Minimum slick thickness needed to support combustion on cold water was found to be 2.5 mm. Minimum slick thickness needed to support combustion on room temperature water was determined to be 2 mm.

Burn rates

Burn rates in the laboratory tests were quantified by the decrease in slick thickness and the total burn time. Total burn time was recorded as the time from ignition until natural extinction. Burning oil on saline water at temperatures ranging from 18C to 22C, yielded burn rates from 0.5 to 0.6 mm/min. On water at temperatures of 2C to 6.5C the burn rates ranged from 0.2 to 0.4 mm/min with the exception of the minimum slick thickness test. Room temperature during those tests ranged from 20C to 24C. Water temperatures are given in Table 1 with other laboratory test data and results. Water temperature was measured using a mercury thermometer with the bulb placed 3 to 5 cm beneath the center of the test ring. Water temperature increased less than 2C during each test unless otherwise noted in Table 1.

Wicking agent

Laboratory tests were performed to determine the added burn effectiveness due to the addition of a fumed silica wicking agent to a crude oil slick. Oil was distributed on the water surface with a syringe. CAB-O-SILTM wicking agent was spooned onto the oil surface and allowed to absorb the oil for approximately 10 minutes. The wicking agent was added in a mass ratio of 1 to 10 (1:10) wicking agent to oil (Battelle, 1979). The residue from the cold water test formed balls of oil residue and wicking agent in the cold water tests, so slick thickness measurements were not possible. However, the volume of residue was visually estimated as greater for this test than for the previous test with the same initial slick thickness but no wicking agent. In the

warm water tests, the wicking agent burn residue amounted to 15% of the original oil volume. This equals an overall burning efficiency of 85% by volume. The results of these tests are also given in Table 1.

Percentage of oil consumed by burning

In addition to the minimum slick thickness and burn rates originally sought, percentage burned was easily quantified. Percentage burned by volume was determined for several of the test runs by measuring initial slick thickness and final slick thickness and using this data in the following equation:

$$\frac{d_i - d_f}{d_i} \times 100\% = \text{percentage burned by volume}$$

where:

d_i = initial slick thickness

d_f = final slick thickness

Percentage burned by volume ranged from 60 to 70% on 18 to 22C temperature brackish water and from 40 to 55% on 2 to 6.5C water with the exception of the minimum slick thickness and wicking agent tests. Note that several of the final slick thicknesses and thus burn efficiencies and burn rates are not given. This is because the method of slick thickness measurement was developed after several tests were performed. Percentage burned data is given in Table 1.

ASTM standard tests

The Prudhoe Bay crude oil used in the tests was characterized for reference purposes by specific gravity, viscosity, flash point, surface tension, interfacial tension, percent water, and gas chromatography. The specific gravity was determined with

hydrometers as specified by ASTM D1298-67. The viscosity was measured using a Brookfield Model LVT viscometer at room temperature and an elevated temperature. Viscometer measurements were converted to centistokes using the relationship expressed in ASTM D2161-74, Section 6, and plotted on ASTM D341 viscosity temperature charts for interpolation to ambient conditions. Flashpoint was determined using a Fisher/Tag closed cup-tester as described by ASTM D56-70. Surface tension and interfacial tension with tank water were measured at room temperature (22.5C) using a Fisher Scientific Model 21 Surface Tensiomat. Percent H₂O and bottom solids was determined as specified in ASTM D1796-75. The results of these analyses are given in Table 2. Gas chromatograms were performed on both Prudhoe Bay fresh oil and weathered (topped) oil samples. The differences between the fresh and weathered oil chromatograms were a complete loss of the C₃ peak and a 30% drop in the C₇ peak height, in the weathered oil.

Oil weathering

For the weathered oil tank tests and the precursor laboratory work, 0.3 m³ of Prudhoe Bay crude oil was topped in a 1-m³ capacity rectangular tank, 0.6-m x 1.5-m x 1.1-m deep. With an oil depth of 0.34 m, a 5.6-cm diameter x 58-cm long air sparger was placed in the tank below the oil surface and operated for 28 hours at an air flow rate of approximately 11 cfm. Ambient temperatures averaged 4C peaking at 10C. This resulted in an expected change in physical properties. The flashpoint increased from < 1C to 27C, and the specific gravity increased from 0.891 to 0.901 (measured at room temperature).

TANK TESTING

Summary of the test plan

Four tests were performed in the OHMSETT tank to explore the range of conditions under which a crude oil slick can be burned amidst a broken ice field, and to

determine the effectiveness of such burns. The burn tests were performed in the OHMSETT tank within a 46.5-m² boomed area. The average ice cover in the center of the test area was varied from 45 percent to 60 percent, and average oil slick thicknesses were varied from 2 to 4 mm. Fresh and lightly weathered Prudhoe Bay crude oils were burned. One of the four tests performed demonstrated the effects of a regular (evenly spreading or breaking) wave on the burn behavior. Burn efficiency was quantified by percentage mass loss. Burn times and flame spreading rates were also determined. (Refer to "Calculations" section for details on measuring technique for flame spreading rate, ice coverage, and oil slick thickness.)

Test set up

A timber boom was fabricated on site to delineate the test area into a rectangle 6.1 m x 7.6 m. Ice blocks, approximately 0.53 m x 1.0 m x 0.25 m, were positioned in a pre-determined grid pattern within the boom for each test. The ice blocks were held stationary by a cabling system attached to the boom. Oil was distributed from the main bridge through a 2.5-cm diameter hose. A color video camera provided an overhead view of the test area from the end of a crane boom approximately 15 m above the test area. (See Figure 1.)

Data gathering

Percentage ice cover, average slick thickness, and average channel width were determined using the overhead video recording displayed on a 12-inch color TV monitor screen in conjunction with other measurements. Air temperature, water temperature, wind speed and direction were obtained with a Climatronics Weather Station. To determine percentage burned by mass, 3M Brand Oil Sorbent pads 45 cm x 90 cm were pre-weighed on a spring scale, then deployed to absorb the burn residue from the water and ice surfaces, and re-weighed. (It was found that the sorbent pads absorbed no appreciable quantities of water.)

Safety

A fire control system was provided to insure against the event that burning oil escaped the boom or flames otherwise spread creating a hazardous situation. OHMSETT crew members manned fire hoses, and the Naval Weapons Station Earle Fire Department was on stand-by during each test.

Calm water/fresh oil/45% ice cover test 1

The target conditions for this test were an ice cover in the center of the pack of 55 percent and average slick thickness of 3.0 mm. Thirty ice blocks were deployed in a pattern of 6 blocks x 5 blocks. Seventy-six liters of oil were distributed by sweeping east and west across the test area with the oil distribution hose while moving north to south on the main bridge over the ice and free water surface in the test area. It is useful to note here that the percent ice cover figures are based on the ice cover in the central part of the test area. This is to give the reader an indication of the ice cover through which flame spread. The peripheral areas are not taken into account in this figure.

The slick was ignited at the downwind corner for all tests. To ignite the slick a "firelog" was ignited from an elevated bridge (the OHMSETT photo/video bridge) and allowed to slide along a wire cable across the test area to the desired ignition location. The firelog was constructed of an EthafoamTM log approximately 13 cm in diameter and 32 cm long, wrapped in sorbent. This combination was soaked in crude oil and sprayed with an ether-based starting fluid immediately prior to ignition. The stopwatch was triggered when black smoke first appeared. The burn was considered to be completed when the free-floating oil extinguished.

With winds out of the east at 12 knot, the oil slick was ignited at an ambient air temperature of 4.9C and tank water temperature of 3.8C. (Winds above 15 knot from

the Northwest to Northeast 90° arc or heavy precipitation were defined as "no-go" conditions.) The ice cover in the center of the pack was 45 percent rather than the 55 percent target value due to melting. The total ice surface area was 13 m² and the oil on water surface area was 31 m². The oil covered 13 m² of the ice block surface area. Average channel widths in this ice cover were 0.3-m. Average oil slick thickness was calculated to be 1.7 mm (calculations assumed uniform slick thickness on water and ice). The slick burned for 7 minutes 53 seconds and the weight of the oil residue recovered indicated that 85 percent by mass of the oil had burned off. The flame spreading rate was determined along a channel 0.5-m wide to be 1.3 m/min. After the burn the ice cover had been reduced to 35 percent. The conditions and data from the tests are summarized in Table 3.

During this test with winds at 12 knot from the east, the heat was intense. A great deal of black smoke was generated in this and every test indicating incomplete combustion. At 1 minute 45 seconds into the burn, the water appeared to be boiling at the surface along the east side of the test area. Figure 2 is a photograph taken during this test.

Calm water/fresh oil/45% ice cover test 2

Twenty-five ice blocks were laid out in a grid pattern of 5 blocks x 5 blocks. Four additional blocks were added to fill in the perimeter space between the ice grid pattern and the boom. The target ice cover in the center of the pack was 60 percent. Eighty-three liters of oil were distributed primarily on the water surface at the center of the ice grid pattern. (Some oil was on the ice blocks as stated below.) Other test criteria and procedures were a repeat of the previous test.

At ignition, winds were out of the southeast at 14 knot; air temperature was 8.2C; the water temperature was 5.4C. The ice had again melted significantly since delivery bringing the percent ice cover down to 45 percent. Total ice surface area was

10 m² and the oil on water surface area was 21 m². The oil on ice surface area was 0.3 m². Average channel widths in this ice grid pattern were 0.3-m. Average oil slick thickness was calculated at 4.0 mm. The slick burned for 8 minutes 15 seconds and the oil residue recovered indicated that 95 percent of the oil had burned or evaporated. The flame spreading rate was determined along a channel 0.5-m wide to be 2.4 m/min. The ice cover was reduced to 30 percent after the burn. The burn behavior during this test was very similar to that during the first test. A great deal of black smoke was generated and the burn appeared to be most intense along the perimeter area between the ice grid pattern and the boom.

Calm water/weathered oil/60% ice cover test

After observing the burnability in the conditions of the first two tests the ice cover was increased. Forty ice blocks were deployed in an 8 block x 5 block grid pattern for a target ice cover in the center of the pack of 75 percent. Sixty-two liters of lightly weathered Prudhoe Bay crude oil were distributed on the water surface around the center block.

With winds at 8 knot from the northeast, an air temperature of 4.3C, and a water temperature of 7.7C, the slick was ignited. Ice cover in the center of the pack was 60 percent with a total ice surface area of 16 m². The oil on the water surface area covered 15 m². The oil on ice surface was 1 m². Average channel widths for this test were 0.3-m measured along the north-south direction and 0.2-m measured along the east-west direction. Average oil slick thickness was calculated to be 4.0 mm. The slick burned for 11 minutes and the weight of the oil residue indicated a percentage burned of 90 percent. The ice cover was reduced to 45 percent after the burn. The flame spreading rate determined during the test was 1.5 m/min in a channel 0.2-m wide.

Flames for this test were approximately two-thirds the height of flames in the previous tests. The black smoke emitted during the burn remained in a coherent cloud

for several hundred meters, moving at an elevation of almost 50 m above the ground surface. Not all of the oil residue was recovered. An estimated 2 kg of oil remained afloat on the water surface after the oil retrieval process was completed. Two kg represents 3% of the original oil mass distributed.

Regular wave/fresh oil/45% ice cover test

This test evaluated the impact of waves on burn behavior. The test was attempted twice. For the first wave test, the south side of the boom was removed and replaced with a cable to allow full impact of the waves. In spite of attempts to maintain control of the oil with fire hose spray, several liters of oil escaped to an area beneath the main bridge. With this situation, the slick was not ignited, however the wave proposed for the test was generated and evaluated. The wave was changed from 5.5-m long and 0.2-m high to 2.9-m long and 0.3-m high for the repeat test (based on L and H (1/3) (Smith, 1980). Also the dampening effects of the boom were observed to be negligible so this test was repeated with the south side of the boom in position. For a target ice cover of 75 percent, 40 blocks were deployed in an 8 block x 5 block pattern. Sixty-two liters of fresh Prudhoe Bay crude oil were distributed onto the water surface at the center of the test area.

With winds at 13 knot from the east, an air temperature of 4.8C, and a water temperature of 7.7C, the slick was ignited. Ice cover in the center of the test area was approximately 45 percent with an ice surface area of near 12 m². Average slick thickness, channel widths, and flame spreading rate were not determined for this test.

Waves reached the test area approximately 2 minutes after ignition. The waves drove the oil to the north side of the test area. The slick was ignited on the south (downwind) side and did not burn intensely until reaching the north side with the thicker slick of oil. Some burning oil escaped over the north side of the boom during this test.

The slick burned for 9 minutes 40 seconds. The weight of the oil residue indicated a percentage burned of 85; however 10 percent (of the distributed oil weight) was retrieved outside of the boomed area. This oil may not have burned to the extent of that contained within the boom. The actual percentage burned within the test area is estimated to be between 90 and 95%.

CALCULATIONS

A series of measurements and calculations was required to obtain the average ice channel widths, total ice surface area, total oil surface area, average oil slick thickness, percent ice cover, flame spreading rate and percentage burned by mass. To determine average ice channel width prior to ignition for each test, the ice and boom were traced from a single frame display on the color TV monitor screen. Knowing the dimensions of the boomed area, a scale was derived. Measurements were made directly from the video tracing for the ice channel width values. Ice channel widths were summed and averaged separately for those measured along the north-south direction and for those measured along the east-west direction.

Total oil and ice surface areas were obtained by making a photocopy of the video tracing, cutting the copy along the test area perimeter, and weighing the cut-out on a Mettler H31 analytical balance. The ice blocks were then cut and weighed, as well as the remaining paper to check the mass balance. Using the percent weight of the ice and oil of the total test area, oil and ice surface areas were determined. Average oil slick thickness was calculated using the total oil surface area and the volume of oil used.

Percent ice cover was calculated using average ice channel widths, number of ice blocks and total ice surface area. First the average ice block dimensions were calculated from the number of blocks and surface area, assuming the length of the blocks remained twice that of the width during the melting process. Percent ice cover in the center of the pack was calculated as shown below:

$$\text{Percent ice cover} = \frac{W_{BL} \times L_{BL}}{(W_{BL} + W_{E/W}) \times (L_{BL} + W_{N/S})} \times 100\%$$

$W_{N/S}$ = average ice channel widths in the north-south direction.

$W_{E/W}$ = average ice channel widths in the east-west direction.

W_{BL} = average ice block width

L_{BL} = average ice block length

Flame spreading rate was determined from the overhead video recording. A transparent grid sheet with scaled increments of 0.3 m was overlaid on the video monitor and when a segment showed the spreading of the flame clearly, the starting point and ending point were marked. The elapsed time was derived from the time-date generated on the video screen. By virtue of the fact that the flame spreading was clearly visible during measurement, flame spreading rates were always measured as flames spread against the strongest winds.

Percentage of test oil burned by mass was determined by calculating initial oil weight and weighing the oil residue. Initial oil weight was calculated using specific gravity and oil volume. Initial oil volume was measured to a precision of ± 4 liters.

DISCUSSION OF RESULTS

The laboratory test data exhibited several trends in burn behavior with respect to the water temperature. Burn rates were consistently higher in the room temperature tests in comparison to the tests performed on cold ($< 6.5^{\circ}\text{C}$) water. Percentage burned was also higher in warmer temperature water. Burn time did not vary significantly due to variations in water temperature, however burn time did

increase, as expected, with an increase in slick thickness. The fumed silica wicking agent appeared to increase burn efficiencies on room temperature water. On cold water the wicking agent did not appear to aid in oil removal.

No trends can be derived from the tank work due to the limited number (4) of tank tests, although a comparison of the tank test data to the laboratory illustrates a scaling consideration. Percentage burned in the laboratory was determined by volume. Percentage burned (in the tank) was determined by mass. Assuming an increase in specific gravity in the burn residue compared to that of the initial oil used, the percentage burned by volume figure will be higher than percentage burned by mass figure for the same burn. Laboratory results on cold ($< 6.5^{\circ}\text{C}$) water ranged from 30 to 50% burned by volume. Tank test results ranged from 85 to 95% burned by mass, indicating a substantial increase in burn efficiency in the larger-scale tank tests. This is due to a change in heat transfer "regimes" in the scale-up. It has been shown that there are various regimes of heat transfer dependent on pool diameter in burning (Babraukas, 1983, Blinov and Khudyakov, 1961, and Hottel, 1958). Below a 1.0-m pool diameter, various modes of heat transfer are postulated to occur. Above 1.0 m pool diameter however, burn rates have been found to remain fairly consistent. Wakiyama (1982) reports that a pool of 1 to 2 m in diameter should model the kind of turbulent burning rate that occurs when oil spills burn. (Based on work by Blinov and Khudyakov, 1961, Hall, 1972, and Yumoto, 1971). So although the laboratory work does not correspond to the tank burns, the tank test results should be useful in predicting results on a still larger scale.

In-place burns of Prudhoe Bay crude oil performed during a demonstration by Shell Oil Co. (1983) yielded burn efficiencies of 55% to 85%. In a subsequent study by Ross (1983), burning efficiencies for pooled oil in ice were predicted to range between 80 and 90%. In work evaluating the in-place burning of pooled oil, the burn efficiencies obtained were 80 to 95% (Dickens and Buist, 1981), 90 to 95% (Shell Oil

Co., 1983), and > 95% (Pistruzak, 1981, and Buist, 1983). In a study by Twardus, fresh crude oils were burned in a 1-m square per yielding burn efficiencies of 93 and 94% by mass (Twardus, 1980). Thus most of the available data for burning of pooled oil slicks corresponds to the results of the OHMSETT burn tests of 85 to 95%. The minimum slick thickness needed to support combustion, determined in the OHMSETT laboratory corresponded with that determined during the demonstration by Shell Oil Co., (1983).

SUMMARY

The burn efficiencies of the tank test burns (85 to 95% removed by mass) of Prudhoe Bay crude oil fall within the ranges determined in previous pooled oil burn demonstrations and studies. (Buist, *et al.*, 1983, Dickens and Buist, 1981, Pistruzak, 1981, Ross, 1983, Shell Oil Co., *et al.*, 1983 and Twardus, 1980.) The regular wave generated did not significantly inhibit flame spreading to the entire test area in the percent ice cover conditions tested.

Minimum slick thickness to support combustion on cold (< 6.5C) water is 2.5 mm for the Prudhoe Bay crude oil used in testing as shown in the laboratory results and in agreement with a previous study. (Shell Oil Co., *et al.*, 1983.) Laboratory results are inconclusive regarding the increase in burn efficiency due to a wicking agent. Laboratory results indicated two trends in burn behavior: percentage of oil burned decreases with a decrease in water temperature and burning rates decrease likewise. The burn efficiencies attained during laboratory tests were much lower than those attained during the tank tests due to a scaling factor according to the work of Babraukas (1983) and Wakiyama (1982).

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TABLE 1. LABORATORY BURN TEST DATA/RESULTS
PRUDHOE BAY OIL

Oil Vol. (ml)	Oil Weathered (Y or N) ¹	Wicking Agent (Y or N)	Initial Slick Thickness (mm)	Final Slick Thickness (mm)	Water Temperature (C)	Burn Time (min:sec)	Percentage Burned By Volume	Burn Rate (mm/min)	Notes
4.59	N	N	2.0 ³	N.D. ⁴	22	1:07	N.D.	N.D.	Minimum slick thickness test. Minimum volume of oil to form a continuous slick on the water surface within the aluminum ring.
13.77	N	N	5.0 ³	N.D.	20	4:29	N.D.	N.D.	Burned for 3 seconds then went out. Re-ignited the oil and burned for 4:29.
13.77	N	N	5.0	2.0	20	5:35	60	0.6	
25.21	N	N	9.0 ³	3.5	19	9:41	60	0.6	
25.21	N	N	8.0	2.5	18	11:00	70	0.5	Oil leaked out in a ring extending 2 cm from the aluminum ring.

- ¹ The weathered oil is described in Appendix B. Y = yes, N = No.
- ² Room temperature for all tests ranged from 20 to 24°C.
- ³ Initial slick thickness was calculated rather than measured.
- ⁴ Not determined. See text for further information.

TABLE 1. LABORATORY BURN TEST DATA/RESULTS
PRUDHOE BAY OIL (continued)

Oil Vol. (ml)	Oil Weathered (Y or N) ¹	Wicking Agent (Y or N)	Initial Slick Thickness (mm)	Final Slick Thickness (mm)	Water Temperature ² (C)	Burn Time (min:sec)	Percentage Burned By Volume	Burn Rate (mm/min)	Notes
25.74	N	Y	10.0	1.5	20	11:08	85	N.D.	Some splattering occurred during burn.
8.58	N	N	2.5 ³	N.D.	2	1:07 ⁵	N.D.	N.D.	Minimum slick thickness to maintain combustion.
7.37	N	N	2.5	2.0	4	0:12 ⁵	15	2	Repeat of minimum slick thickness to maintain combustion.
13.74	N	N	5.0 ³	N.D.	4	3:40	N.D.	N.D.	Ignited for 2 seconds twice, then flashed approx. 15 times before ignition.
13.74	N	N	5.0	N.D.	2	4:50	N.D.	N.D.	Ignited for 2 seconds then went out. Re-ignited the oil and burned for 4:50.

- 1 The weathered oil is described in Appendix B. Y = yes, N = No.
- 2 Room temperature for all tests ranged from 20 to 24C.
- 3 Initial slick thickness was calculated rather than measured.
- 4 Not determined. See text for further information.
- 5 No reason is apparent for this difference in burn time.

TABLE I. LABORATORY BURN TEST DATA/RESULTS
PRUDHOE BAY OIL (Continued)

Oil Vol. (ml)	Oil Weathered (Y or N) ¹	Wicking Agent (Y or N)	Initial Slick Thickness (mm)	Final Slick Thickness (mm)	Water Temperature ² (C)	Burn Time (min:sec)	Percentage Burned By Volume	Burn Rate (mm/min)	Notes
9.15	N	N	2.5 ³	1.5	4	2:47	40	0.4	
9.7	N	N	2.5	1.5	5	3:00	40	0.3	
13.74	N	N	4.0	3.0	6.5	5:14	30	0.2	
25.74	N	N	10.5	6.0	3.2	11:29	50	0.2	Water temperature increased from 3.2C to 15.0C during test due to heat of photographic lighting.
25.74	N	Y	10.5	N.D. ⁴	5.4	23:47	N.D.	N.D.	Wicking agent was not completely absorbed into the oil, until 5 minutes of burning. Water temperature increased from 5.4C to 8.6C during test. Dark powdery residue sank to bottom of pan overnight. (After 16 hours.)
12.5	Y	N	3.0	1.5	19	4:34	55	0.4	Small quantity of oil leaked from ring.

- 1 The weathered oil is described in Appendix B. Y = yes, N = No.
- 2 Room temperature for all tests ranged from 20 to 24C.
- 3 Initial slick thickness was calculated rather than measured.
- 4 Not determined. See text for further information.

TABLE 2. RESULTS OF LAB ANALYSIS OF TEST OIL

Sample	Specific Gravity	Viscosity (cSt)	Temperature (C)	(%H ₂ O)	Tension (dynes/cm)	Inter-facial Tension (dynes/cm)	Flash-point (C)
Fresh Oil - Sample No. 1	0.890	30.3	21.6	0.02	25.8	29.7	< 1
	0.897*	62.0*	6.2				
Fresh Oil - Sample No. 2	0.892	31.4	21.6	0.02	26.1	29.7	< 1
	0.900*	62.0*	6.2				
Weathered Oil	0.901	52.2	21.6	0.02	24.3	31.6	27
	0.908*	160.0*	6.2				

* Data extrapolated.

TABLE 3. SUMMARY OF TEST CONDITIONS AND FURN DATA

Wave Conditions	Average Slick Thickness	Percent Ice ¹ Cover	Water Temperature	Burn Time	Flame Spread ² rate	Percentage Burned
Calm	1.7 mm	45-35	3.8C	7:53	1.3 m/min	85
Calm	4.0	45-30	5.4	8:15	2.4	95
Calm	4.0 (weathered oil)	60-45	7.7	11:00	1.5	90
Waves	N.D. ³	45-N.D.	7.7	9:40	N.D.	> 85

1. In the center of the ice pack.
2. Based on 1 discrete measurement in each test.
3. Not determined due to the lack of a video recording after ice deployment and before oil distribution.

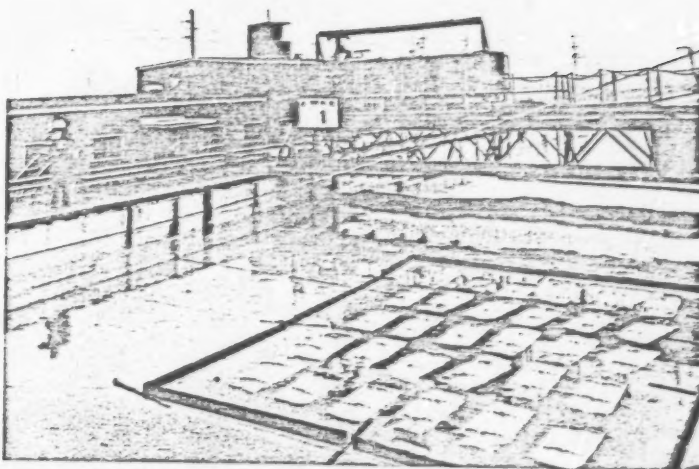


Figure 1. A Sony DXC- 1000 color video camera was positioned approximately 15-m above the boomed area during the tests. Information obtained through the overhead video coverage was used to determine percent ice cover, average oil slick thickness, and average ice channel width.

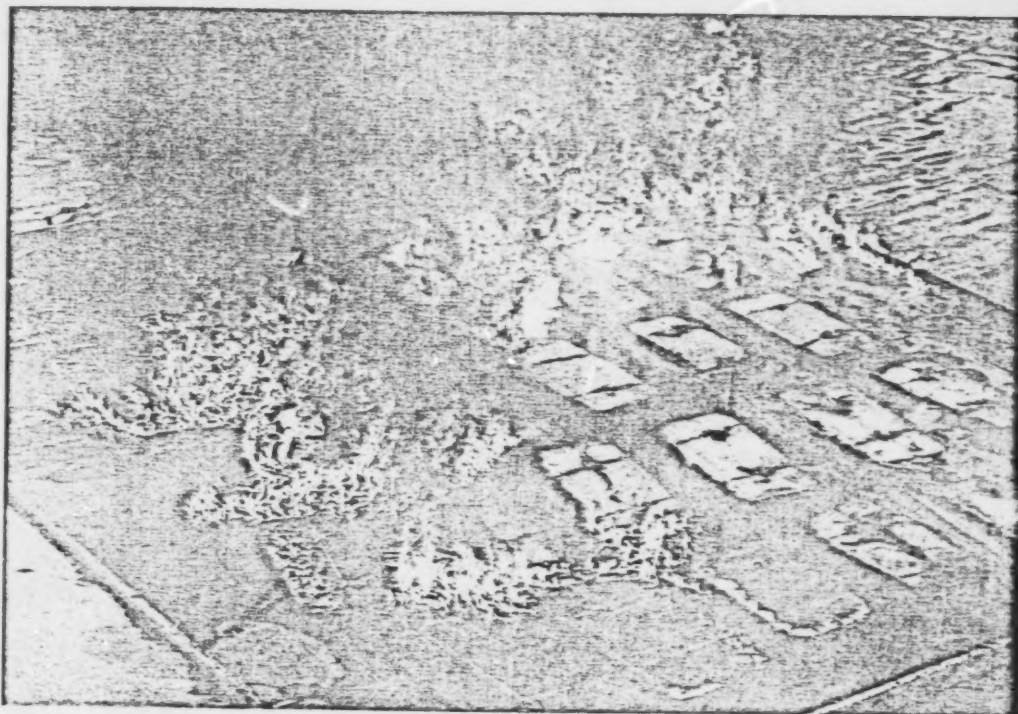


Figure 2. In the first test (calm water/fresh oil/45% ice cover) the slick was ignited in the northwest corner of the boomed area. Flames spread south and east through the ice channels. In this test, oil was distributed over the entire test area rather than from the center of the test area as in subsequent tests.